A Short Course In CHEMISTRY

FOR

Kansas Vocational Schools

BY

W. F. HEARST
Teacher of Vocational Agriculture
ALMA, KANSAS

BROWN & GRINDELL

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The School Book Commission

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FOREWORD

My experience of five years as a teacher of vocational agriculture has led me to believe that in order to better understand soil fertility, plant growth and animal nutrition, the boys who take this course should be taught a little chemistry. I therefore prepared this "Short Course in Chemistry" for use in my own classes, and with no idea of publishing it. However, at the request of Mr. C. M. Miller, State Director Vocational Education; Mr. L. B. Pollom, State Supervisor Vocational Agriculture, and Mr. C. V. Williams, Professor Vocational Education at the Kansas State Agricultural College, who have examined the manuscript, I have consented to its publication for use in other vocational schools in Kansas.

It is in no sense of the word an elementary chemistry text, but simply a short course in that subject containing what I believe boys should know, and can learn about chemistry, that will enable them to better understand certain phases of the vocational work. I have endeavored to put it in understandable language and have avoided as much technical chemistry as possible. I have also omitted material that is found in our regular texts. Since it was not written for publication it is not in the exact form that I should like to have it had I the time to work it over, and no doubt some errors will be found. Some of the more difficult portions have been given for illustration only, and not with the expectation that they be learned. It is primarily a compilation, and I claim originality for only a small portion of it, and for its arrangement.

I am including a list of the apparatus and material that I have procured in order to give this course to my classes, some of which is intended only as illustrative material.

W. F. HEARST.

A Short Course in Chemistry For Kansas Vocational Schools

CHEMISTRY is the science which treats of the material of which all substances are composed, and shows the changes which take place when two substances act upon one another so as to make a new substance.

Everything in the entire universe is composed of elements, either singly or combined. Chemists have discovered about eighty of these elements. A list of these may be found in any text on chemistry, but only a few of the most important will be given here.

Instead of writing the names of these elements the chemist uses symbols which stand for the names. The symbol of an element is usually the first letter, or the first and second letters, of the name of the element. In order to avoid conflicts sometimes the first letter of the Latin name of the element is used. Example: Potassium (K) from the Latin name kalium. Iron (Fe) from the Latin name ferrum. (P) is the symbol for phosphorus and (I) for iodine.

The following are a few of the more important elements and their symbols. Do not pay any attention at this time to the figures following the names of the elements and their symbols, under the heading "valence." This will be explained to you later.

		Valence
Oxygen	O	2 or 4
Hydrogen	H	1
Nitrogen	N	3 or 5
Carbon	C	2 or 4
Phosphorus	P	3 or 5
Potassium	K	1
Iron	Fe	2 or 3
Calcium	Ca	2
Magnesium	Mg	2
Sulphur	S	2, 4 or 6
Chlorine	Cl	1
Sodium	Na	1
Silicon	Si	4
Aluminum	Al	3
Copper	Cu	1 or 2
Lead	Pb	2
Manganese	Mn	2, 4, 6 or 7
Mercury	Hg	1 or 3
Tin	Sn	2 or 4
Zinc	Zn	2

OXYGEN is an odorless, colorless gas and is the most abundant and most important of the elements. It forms about one-fifth of the weight of the air and is not in combination, but is simply mixed with the other constituents. It is also found in combination with other elements in the crust of the earth and in water. Oxygen in the interstices of the soil is an active agent in bringing about many chemical changes, as oxidation of the organic matter and disintegration of the soil particles. It also forms about fifty per cent of the compounds found in plants and animals. Oxygen is a very active element and combines chemically with nearly every other element. This combination with other elements is called oxidation, and the products of this action are called oxides. Oxidation may take place rapidly, as the burning of wood or coal in a fire, or it may take place very slowly, as in the decay of wood, the rusting of iron, or the decay of the tissues of animal and vegetable matter.

HYDROGEN is a very light odorless and colorless gas and is found mostly in combination with carbon and oxygen, as in animal and vegetable matter and with oxygen to form water. It is not found in large amounts in the soil and that which forms a part of the tissues of plants and animals comes largely from the hydrogen in water.

CARBON occurs in three distinct forms, as the diamond, as graphite and as charcoal. It forms a large proportion of the solid matter of all living things. It exists in the combined state in many materials, as calcium carbonate ($CaCO_3$) or common limestone, and as carbon dioxide (CO_2). There are about eighteen tons of carbon dioxide in the air over each acre of the earth's surface. Carbon is the element most closely associated with plant and animal life. It forms a large proportion of the solid matter of all living beings, and the chemical processes of animal and plant life are mainly those in which carbon plays an important part.

NITROGEN is a colorless, odorless gas, the greater portion of which is found free in the air. It constitutes about seventy-nine per cent of the atmosphere and over each acre of land there is about thirty tons. All living matter contains it as an essential constituent, and it is an absolutely essential ingredient in the food of both animals and plants. It must be supplied to animals in compounds known as proteins, in which it is combined with carbon, hydrogen, oxygen and certain other elements. Plants acquire it generally from nitrates, which are simple compounds of oxygen, nitrogen, and some base, as calcium, sodium or potassium.

SULPHUR is a yellowish brittle substance and very inflammable. It is found both free and combined in nature. Sulphur dioxide (SO_2) is poisonous to animals and plants,

while sulphates are necessary. Sulphur is present in the proteins of both plants and animals and when putrefaction of these substances occur is often liberated as hydrogen sulphide (H_2S). The disagreeable odor of decaying eggs comes from the hydrogen sulphide that is liberated.

PHOSPHORUS is a yellowish waxy substance when prepared as an element. It always occurs in a state of combination, chiefly as phosphates, which are widely distributed in small proportions in the rocks of the earth. All fertile soils contain small quantities of phosphates, which are used by growing plants, and through plants by animals. It is a violent poison. It is one of the elements of plant food that is liable to be lacking in a soil that has been cultivated for a long time.

CALCIUM is an easily oxidizable metal difficult to prepare. It is very abundant in nature and always occurs in a combined state. Calcium carbonate ($CaCO_3$), common limestone, is one of the principal forms in which it is found. Its oxide, or a compound of calcium and oxygen, is the important substance "quick lime." This is made by burning limestone, whereby the carbon and a part of the oxygen are removed as a gas. Calcium is an essential constituent of plant food and in the soil is present in a variety of forms as calcium carbonate, calcium sulphate ($CaSO_4$) and calcium phosphate ($Ca_3(PO_4)_2$).

POTASSIUM is a very soft metal which oxidizes so easily that it must be kept away from contact with the air or moisture by immersing it in naphtha. Potassium compounds are very necessary for plant growth and these compounds are liable to be lacking in a soil that has been cultivated for a long time.

SODIUM is a soft metal and resembles potassium somewhat. It is very widely distributed in nature in combination with other elements, one of the most common of which is chlorine, giving us our common salt (NaCl). While sodium is found in the ash of most plants it does not appear to be essential to their growth.

MAGNESIUM is a bright silvery metal and burns in air with an intense and dazzling white light. It is found in the ash of all plants and is one of the required elements of plant food. There is generally in all soils an amount sufficient for crop purposes and it is not necessary to consider this element in connection with fertilizers.

IRON is one of the metals and is so common that it needs no description here. It occurs in nature in a large number of compounds, especially with oxygen. It is one of the essential elements of plant food, but plants require such a small amount that most soils contain an abundant supply.

CHLORINE is a yellowish green gas with a very irritating

and suffocating smell, and of great chemical activity. In the presence of water it is a strong bleaching agent. Chlorine is present in all soils, generally in combination with sodium, as sodium chloride (NaCl), common salt. While it is present in all plants, it does not seem to be absolutely necessary for their growth, as crops have been brought to maturity in its entire absence.

SILICON is a brown solid substance and is extremely abundant in the rocks of the earth's crust. Silica (SiO_2) is a compound of silicon and oxygen and is very abundant, occurring free as quartz, flint and sand. It does not appear to be absolutely necessary as a plant food.

ALUMINUM is a white silvery solid, very light in weight. It is a metal and is the third element in the order of quantity. Aluminum is not found free in nature, and while it is found in small quantities in most plants, it does not seem to be an essential element of plant food.

COPPER occurs free in considerable quantities in nature, as well as in combination. It is a red solid and one of the metals.

LEAD is a soft malleable metal.

MANGANESE is a metal, the most common form of which is pyrolusite (MnO_2). While manganese is found in plants it does not seem to be one of the essential elements.

MERCURY is a silvery white liquid and very heavy. Although it is a liquid at ordinary temperature it is one of the metals.

TIN is a white moderately hard metal, the most common form of which, in nature, is stannic oxide (SnO_2).

ZINC is a bluish white metal and is found in nature as zinc blend (ZnS) and smithsonite ($ZnCO_3$).

MOLECULES AND ATOMS

MOLECULE.—A molecule is the smallest particle of matter that can exist alone and still hold the characteristics of the body of which it is a part. It cannot be seen even with the highest powered microscope. (This definition applies to compounds and is not absolutely true of elements, as you will see in the next definition.)

ATOM.—An atom is the smallest division of matter and is one of the parts of which the molecule is composed. Molecules

are composed of two or more atoms. The molecule of water is composed of two atoms of hydrogen and one of oxygen (H_2O). A molecule of cane sugar consists of twelve atoms of carbon, twenty-two of hydrogen and eleven of oxygen ($C_{12}H_{22}O_{11}$). A molecule of an element would have to consist of two or more atoms of that element. This is the exception to the definition of a molecule given above.

Elements may exist in nature, some of them singly and others in combination with other elements. Some of them may be found in both forms. When they are found in combination the chemist uses the symbols of the combined elements, written one after the other, and calls the resulting expression a formula. (Some authors use the term "Symbol" for the combination as well as the single element.) For example: (HCl) stands for hydrogen chloride, or hydrochloric acid, and means that this substance is composed of one atom of hydrogen (H) combined with one atom of chlorine (Cl). Again, (NaCl) stands for sodium chloride (common salt) and means that sodium chloride is composed of one atom of sodium (Na) combined with one atom of chlorine (Cl).

When more than one atom of an element is present in the molecule of a compound the number of atoms are represented by a small number called a subscript written to the right and below the symbol. For example, (H_2O) is the symbol, or formula, for water and means that two atoms of hydrogen are combined with one of oxygen. In like manner (H_3PO_4) stands for phosphoric acid and means that there are three atoms of hydrogen, one of phosphorus and four of oxygen in the molecule.

From the above you should be able to understand the meaning of chemical formulae, although many of them are far more complex than those used as examples.

A coefficient placed before an element, or a compound, denotes the number of atoms or molecules. Thus, (2H) indicates two atoms of hydrogen and (3NaCl) means three molecules of sodium chloride.

EXERCISES: Read the following symbols and formulae and tell the number of atoms and molecules indicated in each and also the names of the elements and compounds.

O, H, N, CO_2, 4HCl, $5HNO_3$, P_2O_5, $3H_3PO_4$, 2NaCl, 6MgO, $CaCO_3$, $4Al_2O_3$. Others may be added as necessary.

ELEMENTS, MIXTURES AND COMPOUNDS

ELEMENT.—An element is a simple substance; that is, it is not formed by the chemical union of two or more substances. Carbon, hydrogen, oxygen, etc., are examples.

MIXTURE.—A mixture is a substance containing two or more elements that have **not** united chemically.

COMPOUND.—A compound is a substance that is formed by the chemical union of two or more elements. For example: water (H_2O), salt (NaCl), calcium carbonate ($CaCO_3$). When two or more substances act upon each other chemically, they lose their characteristic properties and new substances with new properties are formed.

The following experiment will help you to understand these three definitions.

Weigh out on a piece of paper 3 grams of powdered sulphur and 5.5 grams of iron filings. Each of these represent an element. Mix these two powders as thoroughly as possible and see if they can still be recognized. If they can this is a mixture and not a compound.

Divide the material into two parts and lay one of these parts aside for further use. See if you can separate the steel filings from the sulphur of the other part by the use of the magnet. Also place the material in a test tube and add 3 or 4 c. c. of carbon disulphide (CS_2), shake and let stand for a few moments. Now pour the contents of the test tube onto some filter paper and filter into an evaporating dish. Place the dish over a flame and evaporate the liquid. Examine the residue on the paper and in the dish. Why do the results of this experiment show that the material was a mixture and not a chemical compound?

Place the remainder of the material in a test tube and heat it over a flame. When it has cooled break the tube and remove all particles of glass from the contents. See what effect the magnet will have on this substance. Also try the effect of carbon disulphide. Is this material an element, a mixture or a compound? (Ferrous sulphide (FeS).)

Now place the material in a test tube again and add a few drops of hydrochloric acid (HCl) and note color, odor, etc. What is taking place?

All substances are subject to change. These changes are of two kinds, chemical and physical. When a change takes place that is of such a nature as to break the molecule up into atoms, or to make the atoms form new combinations, then the change is called a chemical change. Let us put some sugar on the hot stove and burn it. The molecules of sugar are destroyed, but other combinations of the elements which were in the sugar pass off into the air. There is nothing left of the sugar. A chemical change has taken place.

Sugar may be ground to a fine powder, or it may be dissolved in water, but it still remains sugar and the molecules are sugar molecules. These changes are physical changes.

CHEMICAL AFFINITY.—There is a tendency on the part of the atoms of certain elements to combine, under favorable conditions, with the atoms of certain other elements. This is called chemical affinity. In like manner when two compounds are brought together, under favorable conditions, there is often

a tendency for the molecules of these compounds to break up into atoms and for these atoms to re-unite and form other compounds. This is on account of the strong affinity that certain atoms have for each other. It is this attraction that holds the atoms of all molecules together and keeps them from breaking up.

Light, heat and electricity are influences that aid in the separation of the atoms of the molecule in one compound and cause them to re-unite to form molecules of an altogether different compound. The breaking up of a compound into its elements, or into simpler compounds, is called chemical decomposition.

CHEMICAL EQUATION.—Chemical action, or reaction, between substances is represented by equations. (Read again the experiment we performed with the iron filings (Fe) and fine sulphur (S).) If we mix these two elements in a spoon or a test tube and heat them over a hot flame, chemical reaction takes place. The iron unites with the sulphur, making a compound called "iron sulphide" (FeS) (ferrous sulphide), a substance altogether different from either iron or sulphur, and with different properties. This is a very simple equation and is represented thus:

$$Fe + S = FeS$$

Let us mix the (FeS) formed in the above experiment with some hydrochloric acid (HCl), then we shall have the following reaction:

Iron sulphide		Hydrochloric acid		Iron chloride		Hydrogen sulphide
FeS	+	2HCl	=	$FeCl_2$	+	H_2S

In this case one molecule of iron sulphide is acted on by two molecules of hydrochloric acid and is converted into one molecule of iron chloride and one molecule of hydrogen sulphide.

It must be remembered that all equations must balance, that is the sum of the atoms before the sign of equality is the same as the sum of the atoms after the sign. The same number of atoms are present but they are arranged in different groups. Do not get the impression that a chemical equation may be made up of any combination of elements that will balance, for this is not true. Comparatively very few chemical changes, or reactions, are possible, and these must be determined by experiments.

The above chemical equations are only representative and many more have been worked out, some of which are just as simple as the above, and others that are more complex. Some of these will be given later but from the above you should be able to understand what is meant by chemical reaction.

All of the most important chemical changes, or reactions, for

our use, belong to one or the other of four varieties, of which the following are examples:

COMBINATION: $Zn + S = ZnS$
Two (or more) substances give one substance.

DECOMPOSITION: $2KClO_3 = 2KCl + 3O_2$
One substance gives two (or more) substances.

DISPLACEMENT: $Zn + H_2SO_4 = H_2 + ZnSO_4$
One element and one compound gives one element and one compound.

DOUBLE DECOMPOSITION: $AgNO_3 + HCl = AgCl + HNO_3$
Two compounds give two compounds.

There are several formulae in the above with which you are not familiar. They are:

Zinc sulphide	ZnS
Potassium chlorate	$KClO_3$
Potassium chloride	KCl
Sulphuric acid	H_2SO_4
Zinc sulphate	$ZnSO_4$
Silver nitrate	$AgNO_3$
Hydrochloric acid	HCl
Silver chloride	$AgCl$
Nitric acid	HNO_3

The above formulae are given, not with the expectation that you learn them at this time, but in order that you may understand the above reactions.

Of the twenty elements, the names and symbols of which you have become familiar, four are gases. You will understand these better if we prepare some of each gas and perform some experiments to determine some of their properties and their uses.

They are:

Oxygen	O
Hydrogen	H
Nitrogen	N
Chlorine	Cl

OXYGEN.—Preparation: The easiest and most practical way for us to prepare oxygen will be to use mercuric oxide (HgO). Place about a tablespoonful of mercuric oxide in an ignition tube (test tube) into which a perforated rubber cork containing a delivery tube has been fitted. (Your teacher will have to help you set us this apparatus, or you may follow the directions given in any text on chemistry.) Now apply heat to the mercuric oxide in the tube and the oxygen will be separated from the mercury. The oxygen will pass through the delivery tube and may be collected in an inverted jar under

water, the gas forcing the water out of the jar. When the water is all displaced the jar is full of oxygen. A piece of glass may now be placed under the mouth of the jar and the jar placed upright on the table. Prepare three or four jars of oxygen in this manner.

The following represents the reaction that has taken place:

$$2HgO = 2Hg + O_2$$

What variety of reaction is this?

What becomes of the mercury?

Oxygen is very active chemically and combines with nearly every other element. This combination with other elements is called oxidation, and the products are called oxides. Oxidation may take place very rapidly, as the burning of coal or wood in a fire, or it may take place very slowly, as in the rusting of iron, the decay of wood, or the decay of the tissues of animal and vegetable matter.

Thrust a glowing splinter of wood into one of the jars of oxygen and see what happens. The reaction is expressed as follows:

$$C + O_2 = CO_2 \quad \text{(Carbon dioxide)}$$

What variety of reaction is this?

Make a little cup in the end of a piece of crayon around which you have wrapped a piece of wire 6 or 8 inches long. Place a small piece of sulphur in the cup and light it so that it begins to burn in the air. Lower it into the jar of oxygen and note results. The following is the reaction:

$$S + O_2 = SO_2 \quad \text{(Sulphur dioxide)}$$

What variety of reaction is this?

Fray out the end of a picture cord wire and wrap the frayed end about the head of a match from which the stick has been removed. Light the match head and lower it into the third jar of oxygen and note the results. This reaction is written as follows:

$$3Fe + 2O_2 = Fe_3O_4 \quad \text{(Ferrosferric oxide)}$$

Why did the burning splinter of wood suddenly burst into flame and burn rapidly when lowered into the oxygen?

What was the difference between the way the sulphur burned in the air and in the oxygen?

What happened to the picture cord wire? Why did not this happen in the air?

If for any reason it is not convenient to prepare your oxygen by using mercuric oxide (HgO), potassium chlorate may be used ($KClO_3$). Take one tablespoonful of potassium chlorate and mix it with an equal amount of manganese dioxide (MnO_2) and proceed in the same manner that you did in preparing the oxygen from mercuric oxide. The manganese dioxide does not

give up its oxygen, but in some way causes the potassium chlorate to give up its oxygen at a lower temperature. The reaction is as follows:

$$2KClO_3 = 2KCl + 3O_2$$

HYDROGEN.—Preparation: Fit a bottle with a rubber stopper having two perforations, one for a delivery tube and the other for a thistle tube to conduct liquids to the bottom of the bottle. Into the bottom of the bottle place a small quantity of zinc chips. Pour dilute hydrochloric acid (HCl) into the thistle tube until the zinc is covered with about one-half inch of the solution. This will soon begin to form many bubbles which is an indication that hydrogen gas is being liberated. This may be collected in the same manner that the oxygen was collected. Since hydrogen gas is very light the bottles in which it is caught must be placed on the table inverted.

A great deal of care must be used in working with hydrogen gas as it is highly explosive when mixed with air, and for this reason the first bottle collected should not be used. The following is the reaction that takes place:

$$Zn + 2HCl = ZnCl_2 + H_2$$

What variety of reaction is this?

What name would you give to $ZnCl_2$?

Wrap a towel around one of the bottles and while someone holds it apply a lighted match to the mouth. What happens?

After the experiment has been running for some time apply a lighted match to the mouth of the delivery tube. In either of the above cases the hydrogen and the oxygen of the air have united and water is formed. The reaction is written as follows:

$$2H_2 + O_2 = 2H_2O$$

Burning hydrogen produces one of the hottest flames known. Hydrogen combines readily with oxygen and chlorine but it does not combine with all other elements. Hydrogen and chlorine unite with explosive violence in direct sunlight, in diffused light quietly, and not at all in darkness. When the combination takes place hydrochloric acid (HCl) is formed.

NITROGEN.—Preparation: Place a small piece of phosphorus on a large flat cork, float the cork on water, and cover it with a jar. The burning phosphorus unites readily with the oxygen of the air, leaving the nitrogen, with some fumes of a compound of phosphorus and oxygen. These fumes will soon be absorbed by the water, leaving the nitrogen comparatively pure.

As the oxygen is combined with the phosphorus, water rises in the jar and fills the space left vacant. This shows the volume of oxygen to be about one-fifth, and the nitrogen to be four-fifths of the air.

Nitrogen is a very inert gas, that is it is not active. Although we taken nitrogen into our lungs every time we breathe we get none of it that is in our bodies from this source. The nitrogen that we obtain comes through the food that we eat, and plants obtain their supply of nitrogen through their roots in the form of nitrates in solution.

Place a burning splinter in the jar of nitrogen and observe what happens. Now place it in a jar of oxygen.

CHLORINE.—Preparation: This is a more complicated experiment than those for the preparation of oxygen and hydrogen. Mix together some manganese dioxide (MnO_2) and common salt (NaCl). Place this mixture in a bottle similar to the one used in making hydrogen and add dilute sulphuric acid (H_2SO_4). Heat gently and chlorine gas (Cl) will be given off, and may be collected in a bottle by means of the delivery tube.

The following is the reaction by which chlorine gas is prepared:

$$MnO_2 + 2NaCl + 2H_2SO_4 = Na_2SO_4 + MnSO_4 + 2H_2O + 2Cl$$

Chlorine is heavier than air and will remain in the bottom of the bottle.

What variety of reaction is this?

Into this bottle of chlorine gas place some pieces of paper that have been written on with ink, some colored pieces of calico and some colored flowers. These should all be moistened a little. What happens?

Let us now examine and make a study of some of the more uncommon of the other elements of which mention was made on page five.

PHOSPHORUS.—Phosphorus unites so readily with the oxygen of the air that it must be kept in bottles filled with water. It should never be handled with dry fingers as it may become ignited and make a very deep and painful burn. Let us remove one of the sticks from the bottle and note some of its properties. You notice that as soon as it comes in contact with the air a disagreeable odor is given off. This odor comes from phosphorus pentoxide (P_2O_5). Phosphorus pentoxide unites readily with water and forms phosphoric acid (H_3PO_4). The reaction follows:

$$P_2O_5 + 3H_2O = 2H_3PO_4$$

Shave some small pieces from the stick **under water.** Now subject some of these shavings to friction under your foot, or under the blade of your knife and see what happens. Matches owe their inflammability to the presence of phosphorus in the head of the match.

Phosphorus is used in considerable quantities by nearly all food producing plants. It is not taken up in its pure form by

the plant, but is in the form of dissolved mineral matter, called phosphates. The most important of these is calcium phosphate ($Ca_2(PO_4)_2$), commonly called phosphate of lime. There are two principal sources of calcium phosphate, the bones of animals, and phosphate rock. Phosphates are an essential part of the food for man and other animals. They are necessary for bone formation and are found in all of the tissues of the body.

When we get ready to study soils and fertilizers we will want to know more about the phosphates.

POTASSIUM.—Potassium is one of the lightest metals and floats on water. Potassium has such a strong affinity for oxygen that when it is placed on water the water is decomposed, which liberates hydrogen. The oxidation is so rapid that enough heat is generated to ignite the liberated hydrogen. With a piece of potassium about the size of a pea try this and note the color of the flame. Do not stand too close to the dish, as there is usually a slight explosion as the last particle is consumed.

The compounds of potassium are widely distributed, being found in the soil and in rocks. These compounds are among the essential elements of plant food. The following are the most important to the farmer:

Potassium chloride	KCl
Potassium carbonate	K_2CO_3
Potassium nitrate	KNO_3
Potassium sulphate	K_2SO_4
Potassium hydroxide	KOH

SODIUM.—The metal sodium is very much like potassium in appearance and properties. With a small piece of sodium try the same experiment that you did with potassium. The compounds of sodium are of very great importance to mankind. The most important are:

Sodium chloride	$NaCl$	Common salt
Sodium nitrate	$NaNO_3$	Chili saltpeter
Sodium carbonate	Na_2CO_3	Washing soda
Acid sodium carbonate	$HNaCO_3$	Baking soda
Sodium hydroxide	$NaOH$	Caustic soda

CALCIUM.—Calcium is not of a great deal of importance as a metal. The following are some of the compounds of calcium with which we should be more or less familiar:

Calcium carbonate	$CaCO_3$	Limestone
Calcium oxide	CaO	Quicklime
Calcium hydroxide	$Ca(OH)_2$	Slacked lime

MAGNESIUM.—This metal is an essential of plant growth,

but its compounds are so abundant everywhere in the soil that plants never suffer for it. The following are important:

Magnesium sulphate	$MgSO_4$	Epsom salts
Magnesium carbonate...	$MgCO_3$	

You are so familiar with the most of the other elements in the list that a study of their properties will not be taken up here. Procure samples of as many as possible of these compounds.

We should now become familiar with three classes of compounds. They are:

ACIDS, BASES, AND SALTS

ACID.—An acid is a substance which contains hydrogen, has a sour taste and has the property of changing vegetable blues, as blue litmus, to red. The hydrogen of an acid may be replaced in a chemical reaction by a metal, the product formed being a salt. Thus, in sulphuric acid (H_2SO_4) the two hydrogen atoms may be displaced by two atoms of sodium, forming the salt, sodium sulphide (Na_2SO_4). The most common acids with which we should become familiar are:

Sulphuric acid	H_2SO_4
Nitric acid	HNO_3
Hydrochloric acid	HCl
Carbonic acid	H_2CO_3
Phosphoric acid	H_3PO_4

Sulphuric acid is a heavy, oily liquid without color when pure, but the commercial acid is colored with impurities given it in the process of manufacture. It is one of the most important acids. Sulphuric acid has a strong affinity for water and will absorb moisture from the air and increase its own bulk. It chars wood that is placed in it. Try this. Also pour some over a lump of sugar and see what happens. This action is caused by taking water away from the sugar and wood and leaving only the carbon.

Nitric acid when pure is colorless and is also one of the most important and powerful acids. It is a powerful oxidizing agent and one of the most corrosive substances known. It will color animal and vegetable tissue containing nitrogen yellow. Nitric acid may be found in the soil, being formed by certain bacterial ferments under favorable conditions. It combines so readily with the minerals in the soil that it exists as an acid but for a short time.

Hydrochloric acid when pure is a gas, but when absorbed by water it makes the hydrochloric acid in the form that it is most frequently used, known as muriatic acid. When it is mixed

with nitric acid in the proportion of three volumes of the HCl to one volume of the HNO_3 it will dissolve gold and platinum. HCl is found in the stomach and aids digestion.

Carbonic acid is formed when carbon dioxide is dissolved in water. The solution has all the properties of an acid, although it exhibits them rather feebly. It tastes slightly sour, turns blue litmus faintly red and neutralizes bases.

Phosphoric acid is important to us only as it is found in feeds and as a fertilizer. We will learn more about it when we study these subjects.

BASE.—A base is a compound capable of reacting with acids to form salts. The compounds of this group with which we want to become familiar are the alkalies and are those that are more soluble. The alkalies will turn red litmus blue. Every base contains (OH), the radical hydroxyl, and usually one atom, but occasionally more than one, as in NH_4, in the other radical. Many other substances, such as sugar ($C_{12}H_{22}O_{11}$) contain (OH), but it is not the presence of these elements, but their presence as a radical, that makes the substance a base. The most important bases with which we care to become familiar at this time are:

Ammonium hydroxide	NH_4OH
Potassium hydroxide	KOH
Sodium hydrate	$NaOH$
Calcium hydroxide	$Ca(OH)_2$

In explanation of the above formulae it may be well to say that in chemistry an element as H, O, Na, and Cl, or a combination of elements that tend to hang together as OH, NO_3, and SO_4 are called radicals. H, O, Na, and Cl are simple and OH, NO_3, and SO_4 are compound radicals. A radical is an atom, or a group of atoms, which behave as a unit in double decomposition.

In the formula NH_4OH, NH_4 is one radical and OH is the other. NH_3 is the formula for ammonia and when combined with water it becomes ammonium hydroxide (NH_4OH). You may wonder why this is not written NH_5O. Although it would not be wrong to write it NH_5O, it is easier in writing reactions to keep it in the form given. NH_4 unites with OH just as K unites with OH. Other important radicals are:

The nitrate radical NO_3, as in potassium nitrate (KNO_3).
The sulphate radical SO_4, as in sulphuric acid (H_2SO_4).
The phosphate radical PO_4, as in phosphoric acid (H_3PO_4).
The silicate radical SiO_3, as in silicic acid (H_2SiO_3).
The chlorate radical ClO_3, as in potassium chlorate ($KClO_3$).

Ammonium hydroxide, although rather weak, turns red litmus

blue, possesses the characteristic soapy taste and feeling, and enters into double decomposition with acids, neutralizing them.

Sodium hydroxide is a white crystalline solid, usually cast into the form of sticks. It is exceedingly soluble in water and its solution gives to objects the smooth soapy feeling which is characteristic of alkalies. Its solution is sometimes called soda-lye and the solid caustic soda.

Potassium hydroxide comes in slender sticks and its properties are much like those of sodium hydroxide. Potassium hydroxide may be used to dehorn young calves. As soon as the horn begins to appear clip the hair from around it, moisten the nub of the horn and rub it well with KOH, being careful not to apply the KOH to too large an area or that it does not run down on the skin of the calf. The stick of KOH should be wrapped in a piece of paper to protect the hand.

Calcium hydroxide (slacked lime) is a white powder. It is slightly soluble in water and the solution is known as lime water. Being cheap, it is used whenever an alkali is needed, provided a dilute alkali will serve the purpose.

Place some ammonium hydroxide in one dish and some nitric acid in another. Dip a piece of litmus paper into one and then into the other and note the results. Keep adding a little nitric acid to the ammonium hydroxide and testing with litmus paper until the mixture has no effect on the paper. The acid has neutralized the alkali and the alkali has neutralized the acid. The following reaction expresses what has taken place:

Acid		Base		Salt		Water
HNO_3	+	NH_4OH	=	NH_4NO_3	+	H_2O

If the water is evaporated the salt ammonium nitrate (NH_4NO_3) will remain as white crystals.

SALTS.—When acids and bases are combined one of the products is water and the other is a salt. Salts effect neither red nor blue litmus. The following is a list of the most common salts:

Ammonium carbonate	$(NH_4)_2CO_3$
Ammonium chloride	NH_4Cl
Ammonium nitrate	NH_4NO_3
Ammonium sulphate	$(NH_4)_2SO_4$
Cupric sulphate	$CuSO_4$
Cupric chloride	$CuCl_2$
Calcium chloride	$CaCl_2$
Calcium nitrate	$Ca(NO_3)_2$
Calcium carbonate	$CaCO_3$
Calcium sulphate	$CaSO_4$
Feldspar	$KAlSi_3O_8$
Lead sulphide	PbS

Potassium nitrate	KNO_3
Potassium chloride	KCl
Potassium carbonate	K_2CO_3
Potassium sulphate	K_2SO_4
Sodium chloride	$NaCl$
Sodium sulphate	Na_2SO_4
Sodium peroxide	Na_2O_2
Sodium carbonate	Na_2CO_3
Sodium nitrate	$NaNO_3$
Zinc chloride	$ZnCl_2$
Zinc sulphate	$ZnSO_4$
Zinc sulphide	ZnS

We have already spoken of one of the varieties of chemical reaction as "double decomposition." In solution, an acid or a base will interact with any salt. Acids also interact with bases, and salts with salts. In all cases the reaction is a double decomposition.

EXAMPLES:

Salt and acid: $AgNO_3 + HCl = AgCl + HNO_3$
Salt and base: $Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2NaOH$
Acid and base: $2HCl + Ca(OH)_2 = CaCl_2 + 2H_2O$
Salt and salt: $2AgNO_3 + CaCl_2 = 2AgCl + Ca(NO_3)_2$

In the above reactions the $(AgCl)$, $(CaCO_3)$, $(CaCl_2)$, and $(2AgCl)$ will settle to the bottom of the test tube as a precipitate. In each case a simple change of radicals occurs.

Write the reactions, using the acids given above, with each of the bases and compare your results with the list of salts, and ascertain whether or not they correspond.

When sulphuric acid (H_2SO_4) unites with a base the salts produced are called **sulphates.** Write the reactions for forming the following salts:

Potassium sulphate	K_2SO_4
Sodium sulphate	Na_2SO_4
Calcium sulphate	$CaSO_4$
Ammonium sulphate	$(NH_4)_2SO_4$

When hydrochloric acid (HCl) unites with a base the salts produced are called **chlorides.** Write the reactions for forming the following salts:

Ammonium chloride	NH_4Cl
Potassium chloride	KCl
Sodium chloride	$NaCl$
Calcium chloride	$CaCl_2$

When nitric acid (HNO_3) unites with a base the salts pro-

duced are called **nitrates.** Write the reactions for forming the following salts:

Ammonium nitrate	NH_4NO_3
Potassium nitrate	KNO_3
Sodium nitrate	$NaNO_3$
Calcium nitrate	$Ca(NO_3)_2$

The compounds that we shall have occasion to deal with that are not included in one or the other of these three groups—acids, bases and salts—are rather few. However, there are compounds that do not belong in either of these three groups. Of these you should be familiar with the following:

OXIDES.—The oxides are compounds of oxygen with the other elements. A short discussion of oxidation has already been given. A few of the most common oxides are:

Mercuric oxide	MgO
Cupric oxide	CuO
Stannic oxide	SnO_2
Carbon dioxide	CO_2
Calcium oxide	CaO
Iron oxide	Fe_2O_3
Phosphorus pentoxide	P_2O_5
Phosphorus trioxide	P_2O_3
Nitrogen oxide	NO

ORGANIC COMPOUNDS.—There are many organic compounds, of which the few given below are examples:

Carbon disulphide	CS_2
Formaldehyde	CH_2O
Alcohol	C_2H_6O
Turpentine	$C_{10}H_{16}$

It may help you to understand some chemical terms to discuss briefly some word endings and prefixes.

The ending **ic** means ordinary or common, as PCl_5 is phosphor**ic** chloride. HNO_3 is nitr**ic** acid. The ending **ous** means less. (PCl_3) is phosphor**ous** chloride and means less of chlorine than in phosphor**ic** chloride (PCl_5). (HNO_2) is nitr**ous** acid and means less oxygen than nitr**ic** acid (HNO_3).

The prefix **hydro** means hydrogen and no oxygen, as in (HCl) **hydro**chloric acid.

The ending **ide** is used in compounds made up of two elements, or one element and a radical, as in (NaCl) sodium chlor**ide** and (KOH) potassium hydrox**ide.** **Hydro-ic** acids yield salts ending in **ide.** Other **ic** acids yield **ate** salts, and **ous** acids yield **ite** salts.

VALENCE.—Valence is the capacity of atoms of different

elements to combine with the atoms of other elements. In hydrochloric acid (HCl), one atom of hydrogen combines with one atom of chlorine. In water (H_2O), two atoms of hydrogen combine with one atom of oxygen. In ammonia (NH_3), one atom of nitrogen combines with three atoms of hydrogen.

Some of the elements have more than one valence, that is they can combine with a certain number of other atoms under one condition and a different number under a different condition. The valence of the different elements is given on page five.

What you have learned from the foregoing pages should enable you to understand the chemistry of the soil, the chemistry of plant growth and the chemistry of animal nutrition.

CHEMISTRY OF THE SOIL.—Soil is the layer of disintegrated rock, mixed with organic matter, which forms the covering of that portion of the earth that we call land. The chemical nature of the soil will depend, to a great extent, upon the character of the rocks beneath.

The following minerals are abundant and of the greatest importance to agriculture: Quartz, feldspars, mica, silicates of magnesia, calcium carbonate, clay, apatite, selenite, iron pyrites, limonite, etc. All of these are represented by chemical formulae, many of which are rather complex. These minerals are the sources from which plants derive the most of their mineral food.

Many minerals when exposed to the action of water are acted upon in such a way as to lead to their disintegration. A portion may be carried away in solution. In many rocks the cementing material, which holds the grains together, is dissolved away and the remainder then readily crumbles. In many rocks are minerals capable of taking up oxygen. On exposure to the air, oxidation takes place and the mineral swells up and often crumbles to powder, thus freeing the other minerals in the rocks. (A good example of oxidation is the white substance that forms on a piece of either sodium, phosphorus or potassium that has been exposed to the air for some time).

Chemical Changes Occurring in the Soil.—The chemical changes going on in the soil are numerous and complex. These changes are hastened because of the great quantity of carbon dioxide (CO_2) produced by the decay of organic matter. The following reaction represents the decomposition of feldspar with the formation of clay, potassium carbonate and silicic acid:

Feldspar		Carbon dioxide		Water	
$Al_2O_3K_26SiO_2$	+	CO_2	+	$10H_2O$	=
Clay		**Potassium carbonate**		**Silicic acid**	
Al_2O_3	+	K_2CO_3	+	$4H_4SiO_4$	

The clay remains behind, but the silicic acid and potassium carbonate may be partially absorbed by the roots of plants.

Calcium phosphate, as it exists in minerals, is nearly insoluble in water, but through the action of soil water containing carbon dioxide in solution, it is changed to more soluble forms and therefore becomes available to plants.

Tri-calcium phosphate $Ca_3(PO_4)_2$ + Carbon dioxide CO_2 + Water H_2O =

Di-calcium phosphate $Ca_2H_2(PO_4)_2$ + Calcium acid carbonate $Ca(HCO_3)_2$

In contact with certain forms of iron and aluminum in the soil the soluble calcium phosphates may be changed to iron and aluminum phosphates and held back in the soil in a finely divided condition, and though quite insoluble in water, may still be dissolved by the acid juices of the plant roots.

Perhaps the most important reactions going on in the soil are those connected with the decay of organic matter and the changes in the state of combination of the nitrogen. The organic matter of the soil is continually being oxidized, the carbon being mainly converted into carbon dioxide. The nitrogen contained in humus is not in a condition to serve as food for ordinary crops, but must undergo a change. This change in the humus is brought about by fungi and bacteria which convert the nitrogen of the organic matter first into ammonia and then into nitrates, forms which are soluble in water and available to the plant. The final nitrification of the ammonia is performed by two species of bacteria, one of which produces **nitrites,** which the other changes into **nitrates.**

The type reactions involved in nitrification may be represented by the following reactions:

Urea $CO(NH_2)_2$ + Water H_2O = Ammonium carbonate $(NH_4)_2CO_3$

Ammonium carbonate $(NH_4)_2CO_3$ + Oxygen $3O_2$ = Carbon dioxide CO_2 + Nitrous acid $2HNO_2$ + Water $3H_2O$

Calcium carbonate $CaCO_3$ + Nitrous acid $2HNO_2$ = Calcium nitrite $Ca(NO_2)_2$ + Carbon dioxide CO_2 + Water H_2O

Calcium nitrite $Ca(NO_2)_2$ + Oxygen O_2 = Calcium nitrate $Ca(NO_3)_2$

Nitrogen gathering bacteria that inhabit the nodules on the roots of clover, alfalfa and other legumes are able to trans-

form the nitrogen of the soil air into organic (protein) nitrogen. Whether this organic nitrogen is directly absorbed by the plant, or whether it first passes through all of the stages of oxidation, as does the organic nitrogen from other sources, is not known.

CHEMISTRY OF PLANT GROWTH.—Of the elements with which you have become familiar the following 14 are commonly present in plants:

Carbon	C
Hydrogen	H
Oxygen	O
Nitrogen	N
Sulfur	S
Phosphorus	P
Potassium	K
Calcium	Ca
Magnesium	Mg
Iron	Fe
Sodium	Na
Silicon	Si
Chlorine	Cl
Manganese	Mn

The last four of these do not seem to be absolutely necessary for plant growth, although they are usually found in plants.

Plants cannot use for food the uncombined elements, but must have their food in the combined form such as water, carbon dioxide (carbonic acid gas) and the mineral salts, all of which are compounds containing these elements in chemical combination. Under certain conditions there are two exceptions to the above statement. Some oxygen is being continually absorbed from the air by all green plants, and the legumes are able, indirectly through the aid of bacteria, to use the nitrogen of the soil air for food.

The chemist divides the plant substance as follows: Water, ash or mineral matter, protein, carbohydrates and fats.

Water (H_2O), composed of hydrogen and oxygen, is the largest single component of plants, forming from 75 to 90 per cent of their fresh weight. It serves a double purpose in plants. Some of it is used for food, while the rest serves as a carrier for plant foods. Only when its food is dissolved in water can this food be taken from the soil by the roots of the plant, or be carried from one part of the plant to another. The plant obtains practically all of its water from the soil through its roots, only a small amount being taken from the air by the leaves.

Next to water, the greatest food material of plants is carbon dioxide, or carbonic acid gas (CO_2). This is obtained from the air of which there is about 28 tons over each acre of the

earth's surface. The carbon dioxide is taken into the leaves through very small openings on their under surface, where it is absorbed by the cells of which the leaves are composed, and used in building plant compounds.

Carbon dioxide is constantly being returned to the air from the processes of combustion, fermentation and animal respiration, so that there is maintained a nearly constant proportion.

Let us make a little carbon dioxide. Procure some marble chips and place them in a bottle arranged as it was for generating hydrogen. Through the thistle tube pour some hydrochloric acid (HCl), and carbon dioxide will be given off. This must be represented by two reactions, as follows:

$$CaCO_3 + 2HCl = CaCl_2 + H_2CO_3 \text{ (Carbonic acid)}$$

This carbonic acid immediately breaks up into water and carbon dioxide.

$$H_2CO_3 = H_2O + CO_2$$

This gas is heavier than air and may be collected in a glass or bottle. Try putting a lighted match into it and note results.

Prepare some lime water by mixing water with quick lime and after the lime has settled to the bottom of the vessel pour off the liquid. This is calcium hydroxide $Ca(OH)_2$. As the CO_2 generates place the mouth of the delivery tube into a glass containing some lime water and note the results. The same results may be obtained by blowing the breath through a tube into the lime water. Why? The following is the chemical reaction:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$$

The calcium carbonate ($CaCO_3$) will settle to the bottom of the glass as a precipitate.

The decomposition of organic matter in the soil liberates CO_2 and this unites with H_2O and forms weak carbonic acid (H_2CO_3).

$$CO_2 + H_2O = H_2CO_3$$

This weak carbonic acid acts on the minerals in the soil and renders the plant food bound up in them available. The carbonic acid combines readily with certain bases to form compounds beneficial to plant growth.

The most important use of carbon dioxide (CO_2) is its direct food for plants. All green vegetation is feeding on carbon dioxide and building up carbonaceous tissues. This feeding takes place only in the presence of the green matter (chlorophyll) of the leaves under the influence of sunlight. The CO_2 breaks up, the oxygen is liberated into the air, and the carbon unites with water in the plant and forms the class of plant tissue substances known as carbohydrates.

There are quite a number of carbohydrates, some of which

will be given later. Carbohydrates are composed of carbon, hydrogen and oxygen, in which the hydrogen and oxygen are in the proportion to form water, that is twice as many atoms of hydrogen as of oxygen.

The sugars, starches and celluloses are the most important carbohydrates. Examples of a few of the more simple ones follow:

Starch $(C_6H_{10}O_5)_n$. The "n" indicates that any multiple of the above formula may be found in the starch molecule.
Glucose $(C_6H_{12}O_6)$.
Cane sugar $(C_{12}H_{22}O_{11})$.

The following is an example of the reaction involved when a carbohydrate is formed from carbon dioxide and water:

$$6CO_2 + 5H_2O = C_6H_{10}O_5 + 6O_2$$

Fats and oils are generally included under the general term fats. Fats are found in both vegetable and animal bodies and are formed of the same elements that make up the carbohydrates; i. e., carbon, hydrogen and oxygen. They differ from the carbohydrates in that the proportion of oxygen is much less, and that of carbon and hydrogen is much greater than in the carbohydrates.

Fats are salts and are formed by the union of compounds called fatty acids and glycerin. The glycerin $(C_3H_5(OH)_3)$ is the base and there are a number of fatty acids of which the following are the most common:

Stearic acid	$C_{18}H_{36}O_2$
Palmitic acid	$C_{15}H_{31}CO_2H$
Oleic acid	$C_{17}H_{33}CO_2H$
Butyric acid	$C_3H_7CO_2H$

By the union of the above acids with glycerin $(C_3H_5(OH)_3)$ the following fats are formed:

Stearin	$C_{57}H_{110}O_6$
Palmitin	$C_{51}H_{98}O_6$
Olein	$C_{57}H_{104}O_6$
Butyrin	$C_{11}H_{20}O_5$

It will be seen from the above that the fat molecules are rather complex. The above is given simply as an illustration and not with the expectation that the student will burden his mind with it.

Protein.—The proteins contain the three simple substances contained in carbohydrates—carbon, hydrogen, and oxygen—and in addition to these, nitrogen, sulphur, phosphorus and other substances. They are very complex chemical compounds

and are not well understood. Of the process of making proteins in plants little is known, except that the plant appears to add nitrogen and other elements to the carbohydrates. These substances have entered the plant in the form of chemical compounds dissolved in the soil water. For example, the following are given as the probable molecular composition of legumin, a protein found in the seed of the field pea, and hordein, found in the barley grain:

Legumin ..... $C_{718}H_{1158}O_{238}N_{214}S_2$
Hordein ..... $C_{675}H_{1014}O_{194}N_{181}S_4$

Ash, or mineral matter is what remains after the dried plant has been burned.

CHEMISTRY OF ANIMAL NUTRITION.—In order to understand how food is used in the body, and the part it plays in maintaining life, it is necessary to discuss briefly the simpler features of digestion as applied to farm animals. The animal resembles the plant in the fact that it can take into its system only dissolved material. It differs from the plant, however, in that it uses, for the most part, only complex compounds, and in the fact that it is provided with a wonderful laboratory in which insoluble substances are changed into soluble ones. This is the digestive tract consisting of the mouth, stomach and intestines.

The process is too complex for detailed treatment and only a few typical illustrations can be given. The carbohydrates are mostly in the form of starch which is insoluble in water and for this reason cannot be absorbed. After the food is mixed with the saliva the starch is changed to some form of sugar through the action of the ptylan, an enzyme which the saliva contains. This can be represented by the following chemical reaction:

Starch		Water		Maltose (sugar)
$2C_6H_{10}O_5$	+	H_2O	=	$C_{12}H_{22}O_{11}$

It must be remembered that it is the enzymes in the different digestive juices that bring about these different chemical changes.

The chemical reactions involved in the digestion of protein have not been worked out. There are so many different proteins, and their structures are so complex, as you will see by referring to the examples already given, that the chemical reactions have not been determined. It is known that the stomach contains a little hydrochloric acid (HCl) which enables the enzymes in the pepsin of the gastric juice to convert the very complex proteins into simpler, though still complex,

products known as proteoses and peptones. While the chemical reaction cannot be given, the following will illustrate the process:

Proteins + Hydrochloric acid = Proteoses + Peptones

The fats, like the proteins, are complex in their structure, and the chemical reactions involved in their digestion have not been worked out. A discussion of the digestive processes may be found in our text on "Feeds and Feeding." However, from what has been given in the foregoing pages, you should be able to understand how these changes are brought about, and these complex compounds broken up into simpler substances to be used by the animal for its nutrition.

SUGGESTED LIST OF APPARATUS AND MATERIAL

APPARATUS

24 test tubes, 6x⅝.
24 test tubes, 6x¾.
24 test tubes, 7x⅞.
24 test tubes, 8x1.
6 test tube brushes.
2 evaporating dishes, 2".
2 evaporating dishes, 3".
2 flasks, 16 oz.
2 flasks, 24 oz.
2 flasks, 32 oz.
11 rubber stoppers, size No. 0 to 10,solid.
11 rubber stoppers, size No. 0 to 10, one hole.
11 rubber stoppers, size No. 0 to 10, two hole.
6 wide mouthed bottles.
2 pair tongs, 9".
6 ft. glass tubing, ¼".
6 ft. glass tubing, 5/16".
6 ft. glass tubing, ⅜".
6 ft. rubber tubing, ¼".
6 ft. rubber tubing, 5/16".
6 ft. rubber tubing, ⅜".
2 pair forceps.
1 graduate 25 c. c.
3 thistle tubes, straight stems.
3 thistle tubes, safety bent stems.
1 doz. reagent bottles.

CHEMICALS

1 lb. sulphuric acid, Com.
1 lb. sulphuric acid, C. P.
1 lb. nitric acid, C. P.
1 lb. hydrochloric acid, C. P.
8 oz. phosphoric acid, C. P.
4 oz. ammonium chloride.
4 oz. ammonium nitrate.
4 oz. ammonium sulphate.
1 lb. ammonium hydroxide.
4 oz. ammonium carbonate.
1 oz. calcium, metal.
1 lb. carbon disulphide.
8 oz. calcium phosphate.
8 oz. calcium sulphate, C. P.
4 oz. calcium chloride, C. P.
4 oz. calcium nitrate, C. P.
4 oz. copper sulphate.
4 oz. copper chloride.
4 oz. copper oxide, C. P.
1 lb. iron filings.
8 oz. ferric oxide.
4 oz. ferric chloride.
4 oz. ferric nitrate.
4 oz. ferric sulphate.
4 oz. graphite.
1 book red litmus paper.
1 book blue litmus paper.
1 oz. magnesium metal.
4 oz. magnesium carbonate.
4 oz. magnesium chloride.
4 oz. magnesium nitrate.
4 oz. magnesium sulphate.
4 oz. magnesium oxide.
1 oz. manganese metal.
4 oz. manganese dioxide.
8 oz. mercuric oxide.
1 oz. potassium metal.
4 oz. potassium nitrate, C. P.
4 oz. potassium chloride, C. P.
4 oz. potassium sulphate, C. P.
4 oz. potassium carbonate.
4 oz. potassium hydroxide, C. P.
8 oz. potassium chlorate.
4 oz. sodium metal.
4 oz. sodium nitrate.
4 oz. sodium hydroxide, C. P.
4 oz. sodium sulphate.
4 oz. zinc chloride.
4 oz. zinc sulphate.
4 oz. zinc nitrate.
Filter paper.
Balances.

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